

DISEASE MANAGEMENT FOR ANNUAL CROPS IN LOW-RAINFALL REGIONS

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Introduction

Most nonirrigated wheat in low-rainfall regions of the Pacific Northwest (PNW) is produced in a winter wheat-summer fallow rotation. The two-year fallow rotation reduces soil quality, increases soil erosion, and is plagued with annual weeds, surface crusting, and diseases of early planted wheat.

Several of these conditions could be resolved if spring crops could be included in the rotation and annual cropping was profitable.

A large Federal investment in research and extension to address these needs in the PNW has been made through a special appropriation named "Solutions to Environmental and Economic Problems" (STEEP) (Michalson et al., 1999). Research teams funded by STEEP are examining annual cropping systems that reduce the amount of land fallowed between winter wheat crops. The prevalence and importance of diseases is anticipated to change as crop management systems are modified. Diseases must be monitored and predicted as new management practices are developed.

Key disease constraints for producing cereals annually include *Cephalosporium* stripe, *Fusarium* foot rot, take-all, *Rhizoctonia* root rot, *Pythium* root rot, *Fusarium* foot rot, and nematodes (Cook and Veseth, 1991; Ogg et al., 1999; Smiley 1996; Smiley and Wilkins, 1993; Smiley et al., 1992). *Cephalosporium* stripe can be eliminated, and *Fusarium* foot rot can be diminished when winter cereals are minimized in the rotation sequence. Severe economic losses from strawbreaker foot rot experienced with winter wheat-summer fallow rotations are greatly diminished or eliminated under direct-drill

(no-till) systems.

Practices that reduce damage from take-all include avoiding short rotations or growing continuous cereals, controlling grassy weeds, planting winter cereals early or spring cereals late, applying starter fertilizer below the seed, forcing the plant to feed preferentially on the ammonium form of nitrogen, using a seed treatment, and reducing the amount of surface residue in the seed row.

Rhizoctonia root rot damage is reduced by rotating cereal crops in cycles of two or more years, planting winter cereals early or spring cereals late, avoiding the "Green Bridge", placing starter fertilizer below the seed, reducing the amount of surface residue in the seed row, tilling immediately before planting, and using a seed treatment. *Pythium* root rot is reduced by planting winter cereals early or spring cereals late, planting high-quality seed, avoiding the "Green Bridge", placing starter fertilizer below the seed, and using a seed treatment. Combining three or more of these plant-health promoting practices will minimize the impact of diseases known to occur in conservation cropping systems.

Objectives of this project were to quantify the impact of diseases in the STEEP team projects near Pilot Rock, OR, and Ralston, WA, and to complement those studies by examining resource-conserving, annual, cereal systems in low-rainfall regions near Echo and Moro, OR. Progress toward those goals is reported here.

Methods

Experimental procedures differed at each location and are described individually.

Pilot Rock, OR

Replicated on-farm research was conducted on two, shallow, soil sites in a 12-in. rainfall zone near Pilot Rock. Scientists, extension agents, and growers met in 1993 to establish experimental parameters. Dr. Dan Ball was the coordinator for this team research. Rotations were established with farm-size equipment on two farms (Gilliland and Shaw farms) during the spring of 1993. Each site contained four replicates of seven cropping systems in randomized complete blocks. Best management practices were used for tillage, residue management, fertilizers, varieties, pesticides, and planting dates. Seven systems were compared: continuous no-till hard red spring wheat, spring barley-summer fallow-winter wheat with conventional chisel plow and either postharvest light disking or a chemfallow treatment applied during early fall, fallow-canola-winter wheat with conventional chisel plow and rodweeding, and winter wheat-fallow with fallow prepared with 1) moldboard plow followed by cultivation and rodweeding, 2) light disking after harvest and then chisel plow and rodweeding, or 3) an early fall chemfallow treatment followed by chisel plow and rodweeding. The goal of the study was to examine difficulties encountered when conventional plow-based wheat-fallow systems are converted to a higher residue and/or a more intensive cropping system. Evaluations included pest and agronomic considerations, profit and economic risk, and compliance with conservation regulations.

Winter and spring wheat plants were collected twice each year and evaluated in our laboratory at Pendleton to identify and quantify diseases on roots, crowns, and foliage. Data were submitted to the project director (Dan Ball) for incorporation into the master database. Dr. Ball plans to summarize grain yields, weed data, and overall results

after the project is concluded during August 1999.

Ralston, WA

Replicated on-farm research was also conducted on a 20-acre site in an 11-in. rainfall zone near Ralston WA. Dr. Frank Young was the coordinator for this team. Scientists, extension agents, and growers met to establish experimental parameters. Rotations were established with farm-size equipment during August 1995. Plots (30 × 500 ft) were in randomized complete blocks with four replicates. The experiment was duplicated on two fields so that each crop in each rotation was grown every year. Best management practices were used for tillage, residue management, fertilizers, varieties, pesticides, and planting dates. Five systems were compared: continuous spring wheat, spring wheat-spring barley, spring wheat-fallow, winter wheat-fallow, and a grower-directed flexible cropping system (growers determine tillage, crops, and timing). The primary focus of this study was to convert the winter wheat-fallow rotation to annual cropping over five years (1995–2000). The goal was to transition into annual cereals first then to incorporate rotation crops to break disease cycles and increase the efficiency of the system. Evaluations included all pest and agronomic considerations, profitability and economic risk, and compliance with conservation regulations. The OSU pathology group at Pendleton collected winter and spring wheat and barley plants once or twice each year. Plants were evaluated to identify and quantify diseases on roots, crowns, and foliage. Data were submitted to the project director, at Pullman, for incorporation into the master database. Progress reports for the overall project were prepared annually in special publications prepared by Dr. Frank Young.

Echo and Moro, OR

Experiments were established in northeast Oregon to complement the work at Ralston. This work was coordinated by the pathology team at Pendleton, led by Richard Smiley. Experiments were performed near Echo on the 66 Ranch operated by the Mader and Rust families, and near Moro on the OSU Sherman Experiment Station. Precipitation at the Oregon and Washington sites is comparable in amount (about 11 in.) and distribution.

A commercial planting of annual no-till hard red spring wheat at the Echo site was heavily damaged by a complex of *Fusarium* foot rot, *Rhizoctonia* root rot and take-all during the fourth consecutive year (1995) of that cropping system. Experiments began in 1996 to determine if root damage could be minimized without altering the overall philosophy of a system designed to reduce soil erosion. The 1996 experiment at Moro followed summer fallow and the 1997 and 1998 plantings were placed over the same site to simulate second- and third-year recropping.

The only tillage on these plots was a postharvest sweep to control Russian thistle. Light cultivation was performed one year to align straw so that it would not plug the single-rank drill used in these experiments. During 1998, a second experiment at Moro was planted directly into standing winter wheat stubble without any sweep or cultivation treatment. Except as noted for specific experiments, fertilizer was applied during February either as a surface broadcast of ammonium nitrate, urea, or ammonium sulfate, or as urea ammonium nitrate solution injected with a spoke-wheel applicator. Rates of fertilizer application varied annually according to interpretations of soil tests taken to 4-ft depth. Weeds were killed by applying Roundup about one month before planting.

This practice increases seedling vigor and yield by breaking the “green bridge” (Smiley et al., 1992). Seed was planted during March into 5 × 30 ft plots with a plot drill equipped with four John Deere HZ openers with modified points (to allow banding fertilizer below the seed) and split-packer wheels spaced at 14-in. intervals. Seed was placed 1-in. deep into moist, cool soil. Unless stated otherwise, seed was treated with Dividend + Apron + Gaucho (1.0 + 0.045 + 2.0 fl oz/cwt), and was planted into five replicated plots at the rate of 20 seeds/ft². Where indicated, a starter fertilizer was banded directly under the seed at the time of planting. The starter fertilizer was a dry mixture of 16-20-0-24 (11 lb N/acre) plus 0-0-60 (8 lb K₂O/acre). Harmony Extra either with or without Bronate was applied to control weeds. Diseases on roots, subcrown internodes, crowns, basal stem and foliage were assessed on seedlings, and white heads were counted as plants neared maturity. Grain yields, test weights, and protein contents were determined. Dr. Penny Diebel, OSU-La Grande, is performing an economic analysis of these experiments.

Twenty spring wheat varieties were evaluated at both locations during 1996 and 1997. In 1998, the variety nursery was repeated at Moro but not at Echo.

During 1996 and 1997, individual experiments were established to determine if yields could be improved by planting a specific variety, treating seed with a broad-spectrum seed treatment, or banding fertilizer below the seed at the time of planting. The best of these practices were examined as an integrated management system during 1998.

Management experiments in 1998 were in a factorial design with three varieties, four seed treatments, and with or without fertilizer below the seed. Varieties included WB 936 (a hard red spring wheat, included to

allow data to be compared with results from earlier years) and representatives of the highest yielding soft white and hard white spring wheats (Vanna and ID 377S, respectively) at these sites during 1996 and 1997. Seed treatments included Raxil Thiram + Gaucho, Dividend + Apron, Dividend + Apron + Gaucho, and Dividend + Apron + Gaucho + Bacillus L324. Starter fertilizer was either applied or not, using the blend and rates described earlier. The experiment at Echo during 1998 followed six spring wheat crops planted annually with no tillage except a post-harvest sweep. Soil tests indicated sufficient residual N to produce the crop with no additional N; none was applied except to examine the starter fertilizer variable. The experiment at Moro was placed into standing winter wheat stubble as a second-year direct seeding.

Results and Discussion

Results are described separately by location.

Pilot Rock, OR

Observations of plant health in the rotations at the Gilliland and Shaw farms sometimes failed to show clear differences among treatments when viewed in isolation for a single site during a single year. It was only after the experiment was nearly complete that important trends became evident. Stress from diseases was amplified by shorter rotations and by higher amounts of surface residue. This observation was exemplified by the three 3-yr rotations: winter wheat produced in a winter wheat-spring barley-summer fallow rotation (chisel plow fallow with either a light disking or chemfallow), and in a winter canola-winter wheat-summer fallow rotation. Rhizoctonia root rot and take-all were less damaging (almost nonexistent) where canola was included as the second crop, rather than spring barley.

We also had an opportunity to compare winter wheat diseases in three 2-yr rotations: winter wheat-summer fallow with 1) moldboard plow inversion tillage plus rodweeding, 2) light disking after harvest and then chisel plowed and rodweeded, and 3) an early fall chemfallow treatment followed by chisel plow and rodweeding. Rhizoctonia root rot and take-all were more damaging in the conservation tillage systems than in the moldboard plow system. Strawbreaker foot rot was more prevalent in the 2-yr chemfallow rotation treatments and least prevalent in the 3-yr rotation that included canola.

Annual no-till hard red spring wheat was heavily damaged by Rhizoctonia root rot and damaged to a lesser extent, albeit still significantly, by take-all and root lesion nematode.

Ralston, WA

Damage from Rhizoctonia root rot was moderate to severe in the winter wheat-summer fallow rotation. In 1998, Rhizoctonia root rot appeared as patches of stunted plants (the “bare patch” phase of this disease) during the spring. Subcrown internode lesions caused by Fusarium foot rot were also significantly damaging. Strawbreaker foot rot and take-all occurred on low percentages of plants and were considered minor and unlikely to affect yield.

Rhizoctonia root rot and take-all were the most important diseases of spring wheat. It also became clear over time that irregularities were occurring in disease severity for specific treatments during the first three years of this experiment. Reversals of disease importance were occurring within comparable treatments during alternate years, depending on which of the two fields (east vs. west side of road) was planted that year. For instance, in 1997 root damage was least where

spring barley followed spring wheat, and the opposite occurred during 1998. During the search to explain these irregularities it was discovered that incomplete information was obtained when the experiment was being designed. The two fields did not have comparable management histories, as had been understood initially. The plot area on the east side of the road, which had a high level of damage from root diseases, had four cereal crops during the five years preceding this experiment; winter wheat in 1990–1991, spring barley in 1992 and 1993, summer fallow in 1993–1994, and winter wheat in 1994–1995. Diseases in the experiment were minor on the west side of the road, where it is now recognized that only one cereal crop was grown during the previous five years; summer fallow (1990–1991), winter canola, summer fallow, winter wheat, and summer fallow (1994–1995). The explanation of these puzzling results during research on root diseases clearly emphasized the importance of rotations as a defense against root diseases.

Echo and Moro, OR

Seedling emergence was excellent in all treatments for this high-residue, minimum-tillage, annual, spring wheat system. Primary constraints to yield included *Rhizoctonia* root rot, take-all, *Fusarium* foot rot, barley yellow dwarf, Hessian fly, root lesion nematode, and low plant density (e.g., the 14-in. row spacing). Yield in 1997 was affected by a mid-spring drought; no rain occurred for six weeks during April and May. Yield in 1998 was influenced by drought through the winter and early spring, plentiful rain during May, and onset of hot, dry conditions during late June and July. Field mice caused considerable damage at Moro during 1998; an adjacent 10-yr-old CRP grassland was plowed at a time when our plot was the only nearby “green island”.

Grain yields (Table 1) at Echo during 1996 and 1997 indicated that varieties with the highest two-year average (>28 bu/acre) included the soft white varieties Centennial, Dirkwin, Penawawa, Pomerelle, Treasure, Vanna, and Whitebird. Only one variety (a durum, WPB 881) yielded less than 25 bu/acre. Test weights were 54–59 lb/bu in 1996 and 57–61 lb/bu in 1997. All hard spring wheat varieties contained protein in excess of 14 percent (range of 14.3 to 16.8 percent) during 1997, and all soft wheat cultivars had protein contents less than 14 percent (range of 12.0 to 13.6 percent).

The three highest yielding soft white cultivars (Dirkwin, Treasure, and Vanna) out-yielded the best hard red (Spillman) and hard white (ID 377S) cultivars by three to five bushels per acre. There are known examples of fields where N has accumulated below the root zone, in low rainfall areas where hard spring wheat is produced continuously. This accumulation reflects the higher amounts of N applied to produce hard wheat for the high-protein market, compared to lower N rates for soft white wheat, destined for low-protein markets. Evaluations contrasting the ecological and economic risks and benefits of hard vs. soft spring wheat production are being conducted. Hard red and hard white spring wheat have higher ecological risk from residual N in the soil profile, higher fertilizer application costs, and premium prices paid for high-protein compared to soft white wheat, which requires less fertilizer and is higher yielding but attracts lower prices.

Starter fertilizer at Echo during 1997 led to dramatically earlier and more vigorous growth. Plants were taller and had more tillers where starter fertilizer had been applied. None of the diseases were influenced by fungicide or starter fertilizer treatments. Percentages of prematurely maturing wheat heads (e.g., whiteheads) did not differ among

fungicide treatments but were considerably higher in plots with starter fertilizer than without starter fertilizer. Grain yield was increased by applying starter fertilizer below the seed (29 vs. 22 bu/acre; LSD = 2) but was not affected by fungicide treatments. Test weights (60 lb/bu) did not differ among fertilizer or fungicide treatments.

Grain yield at Moro in 1997 varied from 23 to 45 bu/acre (LSD = 4). Varieties with highest yield (>40 bu/acre) were Dirkwin, ID 377S, Pomerelle, Treasure, and Vanna. Varieties with lowest yield (<30 bu/acre) in 1997 were Klasic, WPB 881, and Yecora Rojo. Spring wheat varieties with highest 2-yr average yields (above 44 bu/acre) were Alpowa, Dirkwin, Treasure, and Vanna. Varieties with the lowest two-year average yields (less than 38 bu/acre) were Klasic, Spillman, WPB 881, and Yecora Rojo. Test weights during 1997 varied from 60 to 64 lb/bu. Protein contents for the 20 varieties ranged from 10 to 14 percent, with two hard types being below 12 percent (ID 377S and Spillman).

Yields at Moro during 1998 (Table 1) varied from 34 to 48 bu/acre and test weights from 59 to 63 lb/bu. Varieties with highest yield (>45 bu/acre) included two that are resistant to Hessian fly: Wawawai, and WB 926. This insect appeared to reduce yields of the susceptible varieties (Alpowa, Treasure, and Vanna) that had highest yields in previous years at Moro. Varieties with lowest yields continued to include Klasic, WPB 881, and Yecora Rojo.

There were no differences in severity of disease among fungicide-seed treatments at either location during 1998. Starter fertilizer led to an increase in incidence of take-all, Rhizoctonia root rot, and pupae of Hessian fly as well as an increase in tillering and plant height. Yield at Moro was improved 3

bu/acre (from 34 to 37 bu/acre; LSD = 2) when Gaucho insecticide was added to the Dividend + Apron treatment. Yields did not vary for the fungicide-seed treatments. Vanna and ID 377S yielded higher than WB 936 (Table 1). Starter fertilizer boosted yield by 7 bu/acre at Moro (from 31 to 38 bu/acre; LSD = 2) and 3 bu/acre at Echo (from 21 to 24 bu/acre; LSD = 2). Test weights varied among varieties (Vanna was 1 to 2 lb/bu less than the others). Test weights were not affected by seed treatment but were increased by starter fertilizer, 0.4 lb/bu at Moro and 1.3 lb/bu at Echo. Protein differed among varieties: at Moro, ID 377S yielded 12 percent; WB 936, 12 percent; and Vanna, 10 percent while at Echo, ID 377S yielded 15 percent; WB 936, 16 percent; and Vanna, 14 percent. Starter fertilizer did not affect protein content.

Summary

The spectrum and intensity of diseases often shifts in concert with changes in cropping systems. The objective of this root disease research was to monitor diseases in each treatment and season them to develop modifications to minimize damage and economic loss from diseases. Special emphasis was given to the root diseases Rhizoctonia root rot, take-all, and Fusarium foot rot. These diseases damaged wheat and barley in experiments near Ralston, Pilot Rock, Echo and Moro. Benefits of a crop rotation were shown at Ralston and Pilot Rock. Yield benefits were shown at Echo and Moro for the selection of a spring wheat variety, application of a seed treatment insecticide, and placement of starter fertilizer directly below the seed at the time of planting. This research had three specific findings:

1. The three, highest-yielding, soft-white, spring wheat varieties (Treasure, Vanna, and Dirkwin) yielded 3 to 5

- bu/acre higher than best hard red (Spillman) or hard white (ID 377S). This finding had one exception: when Hessian fly was active, the highest yields were with the fly-resistant varieties Wawawai and WPB 926R.
2. All modern, fungicide-seed treatments led to yields slightly higher than from untreated seed, but there were no differences among fungicides. This finding also had one exception: Gaucho insecticide increased yield up to 3 bu/acre when barley yellow dwarf and Hessian fly were active.
 3. Starter fertilizer placed directly below the seed led to more vigorous spring wheat seedling growth and grain yields up to 7 bu/acre higher than where no starter fertilizer was applied.

Experiments are being continued and refined to capture further low-cost benefits from minor changes in production practices. This research and extension activity will help determine whether annual cropping systems can improve farm profitability while reducing soil erosion and improving soil quality. Input and output data from each location are currently being evaluated in an economic analysis. Yield data from research at Echo and Moro were posted on Dr. Russ Karow's OSU Cereals Extension WebPage at <http://www.css.orst.edu/cereals/>.

Acknowledgements

Pilot Rock, OR

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Cooperators. Bob Adelman (NRCS, conservation compliance), Tom Golke

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Grower Advisory Committee. 6 growers

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Ralston, WA

Principal Investigators. Frank Young (USDA-ARS, weeds), Kim Kidwell (WSU, spring wheat), and Bill Pan (WSU, soil fertility, crop residue, and water).

Cooperators. Rich Alldredge (WSU, design and analysis), John Burns (WSU, tours & meetings), Steve Clement (ARS, aphids), Ann Kennedy (ARS, residue decomposition), Gary Lee (UI, weeds), Bob Papendick (PM-10 coordination), Bill Schillinger (WSU, water), Steve Ullrich (WSU, barley), Roger Veseth (UI, education and publicity), Doug Young (WSU, economics and risk).

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Table 1. Spring wheat yields (bu/acre) at low-rainfall sites near Echo and Moro during 1996, 1997 & 1998.

Variety and Class		Echo (Buttercreek Area)			2-yr mean†		Moro (Experiment Station)				3-yr mean†	
		1996	1997	1998‡	rank	yield	1996	1997	1998	1998‡	rank	yield
Alpowa	SW	23.5	27.9		12	25.7	50.7	37.6	41.4		6	43.2
Calorwa	Club	25.7	29.0		7	27.4	48.7	31.9	36.3		14	39.0
Centennial	SW	24.5	31.6		6	28.1	45.5	39.0	39.3		11	41.3
Dirkwin	SW	28.3	33.1		3	30.7	45.7	42.8	46.9		1	45.1
ID 377S	HW	25.7	28.9	24.4	8	26.3	43.3	40.7	42.6	35.7	8	42.2
Klasic	HW	24.5	26.9		12	25.7	38.7	26.1	35.5		20	33.4
Nomad	HR	24.9	26.7		11	25.8	47.1	30.6	42.1		12	39.9
Penawawa	SW	30.8	28.9		4	29.9	46.5	35.4	37.0		13	39.6
Pomerelle	SW	27.2	30.2		5	28.7	41.4	45.1	44.2		4	43.6
Spillman	HR	27.7	26.8		8	27.3	44.4	30.5	40.3		15	38.4
Sprite	SW	28.6	25.8		9	27.2	45.5	32.9	35.0		16	37.8
Treasure	SW	31.4	32.2		1	31.8	47.1	41.6	44.3		2	44.3
Vanna	SW	30.5	31.2	25.6	2	29.1	51.0	40.5	39.9	36.8	3	43.8
Wawawai	SW	24.9	29.6		8	27.3	44.8	37.4	47.6		5	43.3
Westbred 906	HR	24.9	26.1		13	25.5	48.6	30.9	44.6		10	41.4
Westbred 926	HR	26.4	25.2		11	25.8	48.9	31.8	48.0		7	42.9
Westbred 936	HR	23.9	26.1	16.9	14	22.3	48.0	32.1	44.5	32.0	9	41.5
Whitebird	SW	25.7	30.5		6	28.1	43.3	33.9	35.1		17	37.4
WPB 881	Durum	21.3	19.9		15	20.6	44.6	26.7	33.8		19	35.0
Yecora Rojo	HR	23.7	29.3		10	26.5	48.5	23.3	35.4		18	35.7
mean		26.2	28.3	22.3		27.0	46.1	34.5	40.7	34.8		40.4
P > F		0.15	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01		<0.01
LSD (P < 0.05)		ns	5.4	1.8		2.6	4.6	4.3	5.7	1.8		3.5

†Rankings include duplicate entries (more than one #8, etc.) for entries with equal yield. Management trials (§) in 1998 had 3 varieties and were not included in means averaged for each location.

‡Management trials. Seed treatments did not boost yields. Starter fertilizer below seed boosted yields at Echo and Moro 3.2 and 6.8 bu/acre, respectively.

Echo: Minimum-till annual spring wheat; the 5th, 6th and 7th years were harvested in 1996, 1997 and 1998. The plot area was tilled once with a shallow (3-in. deep) sweep following each harvest, and was otherwise handled as “no-till”. For comparison, winter wheat varieties in an adjacent WW/fallow rotation yielded 40–77 bu/acre in 1998; Stephens yielded 69 bu/acre and was boosted to 77 bu/acre when treated with Gaucho.

Moro: Spring wheat in 1996 followed winter wheat harvested in 1994 and fallow in 1995. The variety trial area was cropped annually thereafter, and was tilled shallow between crops. Winter wheat yields were 50–86 bu/acre in nearby experiments during 1998; Stephens was 86 bu/acre. The management trial during 1998 was direct drilled into standing winter wheat stubble.